RESEARCH DEPARTMENT

REPORT ON INTERNATIONAL COLLOQUIUM ON WAVE PROPAGATION

PARIS — 17th–21st SEPTEMBER 1956

Report No. A-044

(1957/2)

THE BRITISH BROADCASTING CORPORATION

ENGINEERING DIVISION

RESEARCH DEPARTMENT

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1. GENERAL

The above Colloquium was held at the Conservatoire National des Arts et Métiers, Paris, under the auspices of the Comité National Français de Radioélectricité Scientifique and the Société des Radioélectriciens. Representatives of fifteen countries were present, including ten from Great Britain (Admiralty, Air Ministry, B.B.C., D.S.I.R. (three), M.W.T., S.T. and C. and Universities (two)). A large number of Papers were presented on (a) ionospheric and (b) tropospheric propagation. The ionospheric and tropospheric sessions took place concurrently, so only what appeared to be the more interesting of each could be attended. The Papers are to be published in a special number of "Onde Électrique" and so far only very brief abstracts of their contents are available. This report will not attempt to deal with the Papers in any detail, but will aim to bring out a few of the more important points and to summarise the general sense of the Colloquium.

2. IONOSPHERIC

2.1. Anomalies in Propagation

There were several Papers on this subject, most of which tended to indicate that the geometric-optical theory of wave propagation is not adequate fully to explain transmission of radio-waves via the ionosphere. DIEMINGER cited experiments over a 1300 km path between Lindau and Helsinki, using sweep-frequency methods, in which he found major discrepancies between the echoes received and the MUF as calculated from vertical incidence measurements. These discrepancies can only be explained by scattering from inhomogeneities in the ionosphere. RAWER also finds such discrepancies, and stressed that the laws of geometric-optics are difficult to apply to transmission over very long distances, where many modes may occur. But there is also propagation outside the realm of geometric-optics, i.e. scattering at the ground, from inhomogeneities in the layer, from meteoric trails, from ionospheric turbulences, etc., and allowance should be made for these effects. Our present knowledge, however, does not show exactly how this is to be done. HARNISCHMACHER gave a Paper on ionospheric winds, saying that they have a vector which rotates clockwise about 30° per hour, and thus making a complete rotation between sunrise and sunset. PFISTER described results of rocket flights in E region, stating that they showed that, superimposed on the smooth stratified ionosphere, is an irregular blobby structure, confirming the existence of (a) stratified ionisation and (b) turbulences.

2.2. Auroral Effects

LITTLE described measurements of absorption in the auroral zone, a subject on which observation is badly needed. The absorption is highest (10 dB at vertical incidence) during daylight and at the equinoxes. Night-time absorption is associated with auroral activity and correlates with the magnetic K index. It is not uniform across the sky, i.e. is very localised. This high latitude absorption is associated with corpuscular bombardment of the atmosphere, and is due to ionisation at heights below 95 km. RYBNER and UNGSTRUP described ship experiments in which signals from Denmark always became weak off Greenland, which was found to be due to a ring-shaped absorption area surrounding the geomagnetic pole and roughly coinciding with the auroral zone.

2.3. Ionospheric Predictions

MINNIS pointed out various ways in which the 12-month average Sunspot Number is unsatisfactory as an index on which to base prediction work, the principal of which are its rather large and erratic variations and the fact that it is only available up to a date six months back. He proposed to substitute for it an index (I_{F_2}) based on the variations in the ionosphere itself. This is obtained from the measurements of $f^o{}_{F_2}$ at three observatories, one each in northern and southern mid-latitudes and one near the equator. SIMON described a method of predicting ionospheric disturbances based on a classification of observed sunspots into active (R) and quiet (Q) spots. Only the former are of significance. Following the CMP of R spots there is a decrease in $f^o{}_{F_2}$, especially at night, for between two and six days.

2.4. Scattering

SAXTON dealt with scatter experiments in this country, with which we are already familiar. EASTMAN made an interesting point as to whether the scattering is due to meteors or to turbulences, on which SAXTON remains doubtful. He mentioned that, with one receiving station at the end of the Great Circle path from a scatter transmitter, two other receiving stations were established, one on either side of the Great Circle path and well off it, with their aerials directive, not on the transmitter, but on the scattering region at the centre of the Great Circle path. The point is that meteor activity varies diurnally across the path so that scattering due to their effects would be towards the west during the first part of the day and to the east during the second part. The field strength at the three receivers was compared and during the first part of the day the strongest field was obtained at the westerly station and during the second part at the easterly one. Only for a time around noon did the Great Circle station have the strongest field. Furthermore the weak field obtained at the diurnal minimum of field at the Great Circle station was much improved by the use of the easterly station. BANERJEE's Paper described A.I.R. experiments on scatter on short-wave C.W. transmissions. A scattered component was almost regularly received and was intensified by the thickening of the layer. It was associated with multiple reflections caused by undulations at the lower fringe of the layer. Another Indian Paper reported scattering observed from the F_2 layer and interpreted it as due to turbulence in that layer.

2.5. Summary

The most important point arising from the ionospheric Papers is that our conception of ionospheric propagation up to now has been far too simplified and what was thought to be a simple case of geometric-optics is in fact much more complex. The movements, inhomogeneities and scattering processes in the layers may give rise to propagation mechanisms not covered by the theory and hence we have discrepancies between the calculated MUF's and those observed in practice. Our calculated MUF's are therefore, in most cases, not more than good approximations, and the empirical method of applying them to multi-hop transmission (the two-control point method) is open to considerable criticism. It may be noted that we in the B.B.C. have realised the fact that these discrepancies existed for many years, and have stressed them continuously. Their existence and cause is now obviously generally realised, but the matter is so complex that we still have no practical information as to how to deal with them. The impression given by RAWER is that only machine calculation can provide a real solution. However there is the possibility of making an empirical correction to the calculated MUF in order to allow for these scattering effects, and a long period study of four circuits is being made at Research Repartment in order to learn more about this.

The other outstanding thing is the growing importance of ionospheric scatter systems (not for broadcasting) and the fact that these are likely to become an important part of the communication network, with, perhaps, a relief from a certain amount of interference, because of the decreasing need for multi-frequency operation in point-to-point communication.

3. TROPOSPHERIC

3.1. Meteorological Factors

MISME, in describing attempts to correlate meteorological and radio data, made the following points. Firstly, that the passage of weather fronts across the transmission path gives rise to fading, secondly, that isolated showers may cause deep fading but have also been observed to cause the beam to converge so as to give a greater than free-space field, thirdly, that a gradual variation in refractive index due to a changing air mass sometimes produces an equal variation in reception, and fourthly, that, in the siting of tropospheric relay stations there should be no *systematically* changing air masses between transmitter and receiver, i.e. each relay section should extend solely over sea or solely over land. A Paper by DU CASTEL also dealt with the correlation of meteorological and radio data all over France, for v.h.f. beyond-the-horizon transmission. Some degree of correlation is obtained, the important meteorological factors to study being (a) refractivity at ground level and (b) rate of increase of refractive index from ground up to 3300 ft (1006 m). BEAN dealt with the correlation between transmission loss and atmospheric refractivity, and with the daily, annual and geographic variations in both. WONG has developed a system using machine methods for the calculation of ray paths. His ray pattern pictures, each displaying the paths of hundreds of rays under different conditions of atmospheric refractivity, give one a clear picture of the complex nature of the

atmospheric effects upon the transmitted energy.

3.2. Microwave Transmission beyond the Horizon

MORROW stated that in U.S.A. measurements on 400 Mc/s at distances up to 750 miles (1200 km) show that reliable communication can be achieved over these distances. At 600 miles (962 km) the median transmission loss exceeded 0·1% of the time in winter is about 125 dB below the free-space value, the attenuation with distance being about 0·1 dB per mile. The equipment necessary was a 50 kW transmitter, 60 ft (18 m) diameter aerial and S.S.B. receivers with space diversity. A high performance A.G.C. system is necessary to overcome the large signal fluctuations. S.S.B. signals are superior to those with f.m. BEAN described methods of estimating the transmission loss due to gaseous absorption in tropospheric scatter transmission on frequencies 100-50 000 Mc/s over 100, 300 and 1000 miles (160, 480 and 1600 km), and found that the total path absorption can be correlated with the meteorological parameter of absolute humidity. CABESSA described results obtained from operation of a large number of stations in Greece, operating over water paths on 2000 Mc/s. He stated that the results confirm the dependence of tropospheric propagation upon meteorological conditions and showed the great value of space diversity for obtaining high quality reception. LACY's Paper described experiments over a large number of paths in mountainous country in California, mainly on 50-500 Mc/s, wherein the phenomenon of obstacle gain was deliberately exploited to extend the range along non-line-of-sight paths. By this means 20-30 dB less path loss could be obtained as compared to tropospheric scatter transmission, and 70-80 dB as compared to smooth earth paths.

3.3. Summary

The most important points from the tropospheric sessions that could be attended appear to be as follows. Our ideas about v.h.f. and u.h.f. tropospheric propagation and about the possible utilities of services on these frequencies are undergoing radical alteration. What was at first thought to be a line-of-sight case of propagation has already been shown to suffer no such limitations and to be utilisable for wide-band transmissions to distances far beyond this. And these distances, and the quality of service achievable over them, are rapidly being advanced. At the same time this type of propagation becomes increasingly more complex, as compared with the original ideas, being intimately bound up with meteorological phenomena of great complexity. The great value of space diversity in preserving the coherence of the tropospherically scattered signal at long distances was particularly stressed.

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